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ARTICLE

A Case Study on the Decentralisation of Lifelong Learning Using Blockchain Technology

Alexander Mikroyannidis, Allan Third and John Domingue

Blockchain technology provides a decentralised peer-to-peer infrastructure, supporting openness, transparency, accountability, identity management and trust. As such, the Blockchain has the potential to revolutionise education in a number of ways. Blockchain technology offers opportunities to thoroughly rethink how we find educational content and training services online, how we register and pay for them, as well as how we get accredited for what we have learned and how this accreditation affects our career trajectory. This paper explores a case study on the decentralisation of lifelong learning using Blockchain technology. In particular, we investigate the different scenarios and requirements for making online education and lifelong learning more open and decentralised, while placing lifelong learners in control of their learning process and its associated data. Additionally, we discuss various approaches to the Semantic Blockchain and the applications of these approaches on education.

Keywords: Blockchain; Decentralisation; Lifelong Learning; Accreditation; Semantic Blockchain

1. Introduction

The emergence of the Blockchain promises to disrupt education by offering the technological means to decentralise it. Blockchain technology offers a decentralised peer-to-peer infrastructure where privacy, secure archiving, consensual ownership, transparency, accountability, identity management and trust are built in, both at the software and infrastructure levels. Although Blockchain technology introduces immutability and trust, we should also take advantage of the vast wealth of existing data and standards for decentralised data publication and consumption on the Web.

One of the core design principles of the Semantic Web is the assumption that data can be published anywhere online, and by anyone, and that it should be possible to query and integrate that data without aggregating it all into a central location. We argue here that a *Semantic Blockchain*, encouraging interoperability between Blockchain platforms and the Semantic Web, is essential to get the most out of both technologies. This is especially important in the education sphere, where learning experiences and accreditation can be acquired from diverse independent sources and according to different learning approaches, contexts and standards, but which still need to be drawn together to form a coherent and understandable picture of an individual's lifelong learning.

The remainder of this paper is organised as follows. Section 2 presents related work in the field of Blockchain applications in education. Section 3 presents a decentralised approach for online education based on the Blockchain, as well as a scenario showcasing the benefits of this approach for lifelong learners. Section 4 discusses the different approaches to the Semantic Blockchain and their applications to online education. Section 5 describes a case study in lifelong learning that aims to deploy decentralisation solutions in order to address a variety of requirements, including immutability, transparency and data privacy. Finally, the paper is concluded and the next steps of this work are outlined.

2. Related work

Education today is still controlled mostly by educational institutions, which offer quality, credibility, governance, and administrative functions. This model is not flexible enough and poses difficulties in recognising the achievements of a lifelong learner in informal and non-formal types of education. As a result, a lifelong learner's transition from formal to informal education and vice versa can be hindered, as the achievements acquired in one type of education are not easily transferable to another (Harris & Wihak 2017; Lundvall & Rasmussen 2016; Mayombe 2017; Müller et al. 2015). Generally, lifelong learners have limited control and ownership over their learning process and the data associated with their learning. This indicates the need for a decentralised model across all types of education, offering learners with a framework for fully controlling how they are learning, how they acquire qualifications and how they share their qualifications and other

learning data with third parties, such as educational institutions or employers (Mikroyannidis, Third & Domingue 2019; Mikroyannidis et al. 2018a).

Blockchain technology can be used to enable individuals to own their official records in a tamper-proof format and share them with third parties for instant verification. To this end, Blockcerts¹ has been developed as an open standard for issuing and verifying records on the Blockchain. The Blockcerts standard allows educational institutions or individuals to develop their own software for issuing and verifying certificates. Blockcerts is compatible with other open specifications and standards, including IMS Open Badges,² W3C Verifiable Credentials³ and W3C Linked Data Signatures.⁴ Blockcerts has seen considerable worldwide adoption, with several educational institutions and start-ups using it to develop their own certification solutions (Grech & Camilleri 2017).

In 2014, the University of Nicosia issued the first academic certificates whose authenticity can be verified through a Blockchain, to students who successfully participated in or completed a course in digital currency.⁵ This experience was replicated by the Holberton school in 2015.⁶ A key advantage of both of these initiatives is the fact that claims can be verified easily and that the verification does not require any effort or response from the host institution. In fact, the host institution does not even have to exist at the time of the verification request.

In 2015, the MIT Media Lab started issuing digital certificates to members of their broader community, in recognition of the contributions they value and to acknowledge membership of the Lab.⁷ Stemming from this development, the Learning Machine⁸ start-up was launched based on the Blockcerts standard. Learning Machine has developed a set of tools for institutions to issue, track and verify Blockchain-based certificates.

In 2016, Sony Global Education announced that it was developing a new educational infrastructure based on the Blockchain.⁹ This infrastructure is built on top of the IBM Blockchain¹⁰ platform and offers a function for authentication and control of usage rights to educational data, as well as an API for handling these rights aimed at educational institutions. This infrastructure allows students to freely and securely share certain academic parameters (e.g., time taken to answer questions in exams) with relevant parties (e.g. academic evaluation bodies).

A number of Blockchain start-ups have as their focus the encoding of CVs onto a Blockchain. Some of these start-ups are APPII,¹¹ Gradbase¹² and Digimaat.¹³ APPII allow their users to create an online profile that showcases academic accreditation, awards and experiences, coupled with personal aspirations onto their Blockchain-based platform. These profiles are automatically matched to job postings through machine learning constructed algorithms. Gradbase have developed eStamp, a scannable image that can be added to CVs to ensure their validity. Like Learning Machine, Digimaat place student accreditation onto the Bitcoin Blockchain.

Additionally, Blockchain technology has been used to attract funds towards helping students pay their university expenses. In 2013, a college student collected over

\$24,000 in Bitcoin donations after holding up a sign with a Bitcoin QR code during a sports event broadcast.¹⁴ Partially inspired by this idea, EduCoin started in 2014 a crowdfunding initiative to setup an educational finance currency.¹⁵

3. A decentralised approach for online education

Our approach for a decentralised model of educational transactions is shown in **Figure 1**. According to this model, learners create single authored or shared artefacts with their peers. At the same time, learners are enrolled on a number of courses and are making use of additional learning resources. Tutors and other teaching staff are providing informal and formal feedback as the learners complete summative and formative assessment. Central administration bodies are issuing formal certificates according to institutional processes.

On top of these processes, we layer a reputational ecosystem, which allows learners to rate courses, online resources and teachers in terms of ease of understanding and attributes related to their specific learning goals. Learners can also rate each other on a range of qualities including, for example, organisational and communication skills. Our early work in applying this approach to academic reputation can be found at (Sharples & Domingue 2016).

All data about learners' accreditation, work, ratings, formal and informal feedback is stored within a framework where everything is verifiable via the Blockchain. Because of the associated costs, large data files are usually not stored on the Blockchain. Typically, large files are stored elsewhere (off-chain) and referenced using a cryptographic hash. In the model depicted in **Figure 1**, we propose the use of IPFS for storing the learner's documents. This solution reduces storage costs and, at the same time, enables the validity of a document to be checked.

The following scenario demonstrates the potential impact of this decentralised approach on lifelong learning. Let us consider Jane, who works as a Junior Data Analyst in a London-based company. She is 30 years old and holds a B.Sc. in Computer Science. She is keen to advance her career in the field of Data Science; however, her demanding work schedule and daily commute do not allow her to return to full-time education for acquiring further qualifications. She is interested in informal and non-formal methods of learning, but she also seeks to acquire some type of accreditation for her learning.

Jane creates her personal Learning Passport, as shown in **Figure 2**. This is powered by Blockchain technologies and offers, among other things, a learning portfolio, as well as opportunities for social learning and peer mentoring. A core feature of Jane's Learning Passport is the provision of Smart Badges, which allow for detailed recording of accreditation in digital form from both formal and informal learning contexts with additional dynamic features. For example, apart from just recording a learning achievement, a Smart Badge can also offer job or course recommendations (Mikroyannidis et al. 2018b).

Jane enrolls on relevant open online courses offered by Higher Education Institutions (HEIs) in the UK and abroad,

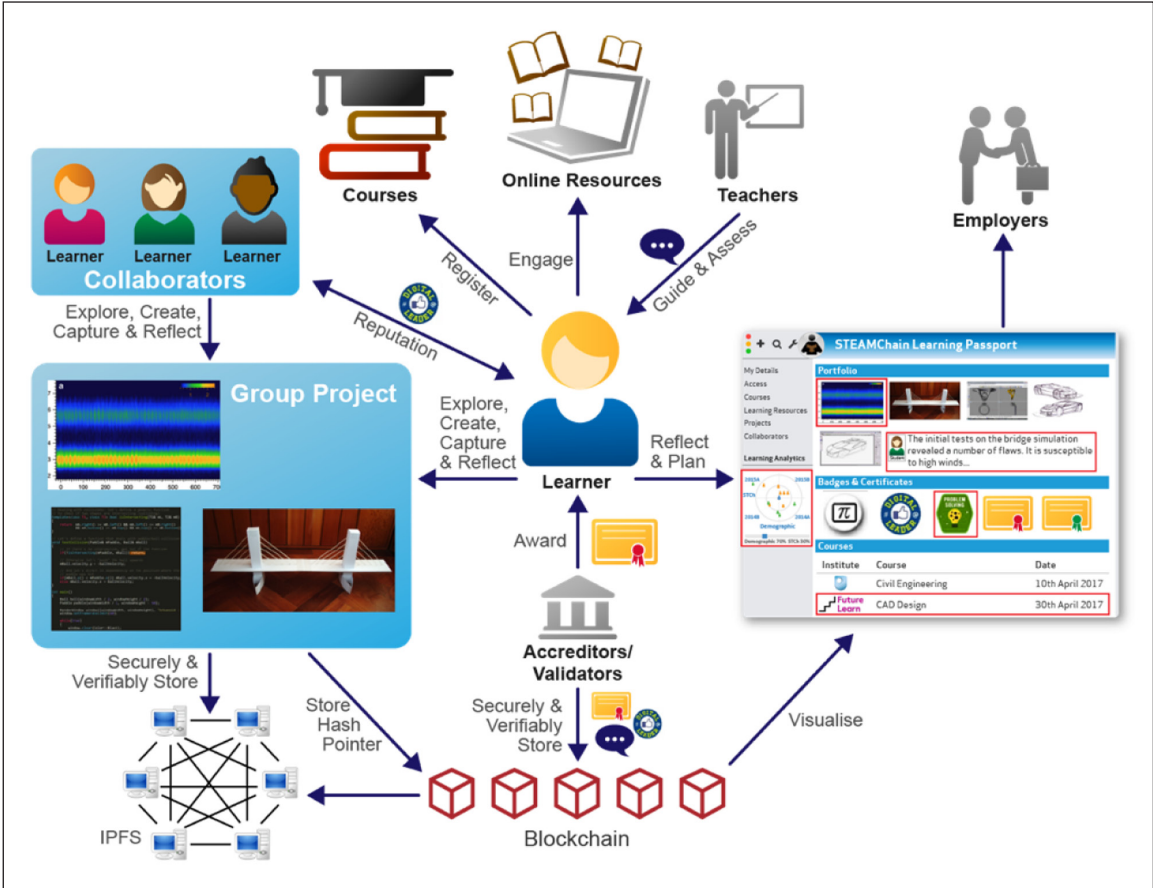


Figure 1: A decentralised model of educational transactions.



Figure 2: Example of a Learning Passport.

as well as relevant Massive Open Online Courses (MOOCs). Upon completion of these courses, she acquires certifications in the form of Smart Badges, which are added to her Learning Passport. Apart from just evidence of learning, the Smart Badges that Jane has earned can be used as dynamic accreditations in a number of ways, thus helping Jane in achieving the following goals:

- finding new courses based on the gap between Jane's current skills and her desired jobs;
- finding new job opportunities that match Jane's qualifications;
- acquiring job promotions based on the new skills that Jane has mastered;
- networking with other professionals and learners with similar backgrounds and learning goals as Jane;
- identifying other learners whom Jane can mentor and tutor in exchange for money or reputation points.

Jane is building her learning portfolio, which consists of the courses she has enrolled on, her assignments and the results of other exercises she has completed, such as quizzes, as well as the Smart Badges she has earned. All data in this portfolio is owned by Jane, who can also encrypt it or select subsets of it for release to others for a fixed duration. For example, Jane can release parts of her portfolio to potential employers two weeks before an interview. She may also offer access to HEIs, educators, trainers and other learners who follow a similar learning journey.

All transactions associated with Jane's Learning Passport are signed and time-stamped. The fact that the transactional record is visible to all and immutable resolves many of the problems associated with identity and fraud. As all data is permanently accessible, different consensual mechanisms can be put in place to link learner work to formal feedback and assessment. If desired, any principles underlying formal statements can be encoded in Smart Contracts, which allow the encoding of organisational rules, so as to be explicit for any interested party.

Jane finds micro-courses that have been produced by independent tutors and gains access to them via micro-payments, similar to purchasing an app on her smartphone. She studies these micro-courses and offers her feedback via ratings that count as reputation points for the authors of these learning materials. Other tutors can also reuse and repurpose these learning materials, upon agreement with the original authors. Jane decides to produce a free micro-course on the R programming language, based on what she has learned, in order to earn reputation points and enrich her portfolio.

Additionally, Jane has access to a network of learners who study together online and mentor each other. She chooses to mentor an early career data scientist in basic data analytics methodologies. She thus gains reputation points for acting as a mentor in this field. In return, she receives tutoring by an expert in Machine Learning and offers reputation points to her mentor. All these transactions are stored on the Blockchain, thus enabling easy transfer between units or organisations if needed and the

automatic detection of any abuse of the system, for example pairs or small groups of employees favouring each other.

Jane is gradually building a strong portfolio in Data Science, with proof that she has gained advanced knowledge based on her earned badges, reputation points, as well as her learning activities and produced artefacts, all of which are recorded and stored in her Learning Passport. Even though she has not returned to formal education, she is now in a much better position to seek a promotion and advance her career.

4. The Semantic Blockchain

The Web is ubiquitous and provides one of the primary interfaces for humans to interact with digital data. By combining technologies especially from the Semantic Web with the Blockchain, the resulting *Semantic Blockchain* has the potential to promote highly interoperable trusted data, with significant applications to education.

The Semantic Web¹⁶ is a collection of technologies and standards for the publication and consumption of machine-interpretable data at Web scale and according to the decentralised Web publication model. In particular, Linked Data, most commonly using the RDF data model,¹⁷ is intended to serve as a standard for self-describing Web data, encapsulated by the Linked Data principles (quoted here from a W3C design note by the Web's creator, Sir Tim Berners-Lee):¹⁸

1. use URIs as names for things;
2. use HTTP URIs so that people can look up those names;
3. when someone looks up a URI, provide useful information, using the standards (RDF*, SPARQL);
4. include links to other URIs, so that they can discover more things.

By using shared *vocabularies* or *ontologies* – Web documents which can establish shared URIs for common concepts and the semantic relationships between them – Linked Data can be published in such a way that the *meaning* of data from independent sources can be interpreted by human or software consumers with little need for manual data alignment. Recent developments in the Semantic Web include the advent of decentralised “data pods” in software such as Solid,¹⁹ from Sir Tim Berners-Lee, which aims to build a user-centred “human-friendly” Web by, in part, supporting individual hosting and control of one's own data. Complementary developments towards user-centredness in the Blockchain sphere include work on *self-sovereign identity* (Baars 2016): technical solutions using Blockchains to manage digital identity in a way which gives users control over their online identity without needing to store personal information in a third-party facility.

The strength of the Semantic Web is in providing an easy framework for *combining* data from multiple sources. Applications of the Semantic Web in education include the Learning Object Metadata for annotation of digital educational material,²⁰ Open Badges,²¹ (from version 1.1

onwards, Open Badges are Linked Data), the ESCO ontology for annotation of skills, competencies and occupations²² and Linked Data harvesting of employment opportunities.²³ Initiatives such as these enable new opportunities, particularly for lifelong learning. For example, an individual planning their future career moves could use Linked Data resources based on the skill requirements of job postings and their existing set of qualifications to identify, automatically, learning materials and opportunities which would be relevant to add to their learning portfolio in order to reach a desired goal. However, the issue of *trust* becomes relevant when data is being drawn from multiple independent sources, particularly when it is valuable. Because of the consequences of one's educational record on career, lifestyle and travel opportunities, there is a strong potential motivation for fraud, for example. How are we to know whether a particular source of data is trustworthy with regard to its contents and history?

We can distinguish between different kinds of trust. Let us start with the example of an educational qualification. In order to be able to accept a presented qualification as accurate, it is important to know where it came from – which institution, for example, for which learning opportunity; to whom it applies – the learner identity; and that the qualification presented is the same qualification that was originally issued. In brief, we need to have trust in *provenance*, trust in *identity*, and trust in *integrity*.

Provenance in educational data covers a number of factors. These include: the history of a piece of education-related material or of certification – when was it created, what was the learning context, what or who endorses it, and so on; the identity of learners and of issuing bodies – is the person presenting, or claiming to be the subject of, some educational data the same as the person it is actually about or from; and integrity – after publication, has the data been altered in anyway? For example, has a qualification been altered to show that it was of a higher level than it actually is?

These trust concerns apply generically outside the education sector as well and require a generic solution. The idea of the Semantic Blockchain is to add a trust layer to the Semantic Web in general, motivated initially by our work and applications in the realm of education.

There are a number of different ways in which Blockchain technology can be used to verify the integrity of data. The core idea remains the same: by publishing data on a Blockchain, a transaction is recorded on the distributed ledger. The transaction record will show the data along with a timestamp showing when it was published. By the nature of the Blockchain, this record is immutable, and anyone with access to the chain can verify that the transaction, its timestamp, and its data contents, have not been altered since that time. Anyone carrying out such a check can be assured that data integrity has been maintained: if the data being presented for verification has been tampered with, it will be possible to detect this and to prove that tampering took place.

Third and Domingue (2017) present a survey of different specific approaches to making data distributed and trusted, varied along several dimensions, from the degree

of data replication, to the levels of integrity guarantee provided, to the cost. The simplest model – in which all data is stored on-chain – has a number of disadvantages. One of these is expense – adding data to a public Blockchain costs money – but even without a cost factor, this poses data protection issues. Educational data contains at least some personal data, and it contravenes good data protection practice and law to store such data in a public space, particularly one which does not allow it to be edited/corrected or deleted. As a result, it is preferable to use methods which keep actual data elsewhere, and store only verification data on-chain: something such as a cryptographic hash, which takes up little space and which can only be calculated from the actual data it represents, and which cannot be used to recreate that data. Distributed storage networks such as the Interplanetary File System (IPFS) are a practical match for Blockchains, being based on similar hashing mechanisms.

To build a Semantic Blockchain, then, we can integrate personal semantic data pods in Solid, using the IPFS network for larger storage, and with both components connected to a Blockchain infrastructure to provide integrity guarantees. *Provenance* is given by immutable timestamped records (as Linked Data) stored alongside the data and which can be cryptographically proven to be associated with that data. *Identity* (including data access control) is provided by self-sovereign identity systems, and *integrity* is provided by the Blockchain itself. Collectively, these support *trust* in the data. By using Linked Data throughout, we ensure the maximum potential for learners and educators to connect their data with that from other sources, and so to get the maximum use from their own data; by particularly using Solid data pods, we ensure that data remains under user control. **Figure 3** shows the main components of the Semantic Blockchain approach we are pioneering in ongoing work, known as *LinkChains*.

The focus on personal interoperable trusted data opens up new possibilities for pedagogical technology and approaches. One of the most exciting is the potential for *lifelong learning analytics*. Instead of learning activity data being collected, and analysed, solely within a specific institution, leading to data silos relating to the same learner being spread across multiple institutions across a lifetime of learning, by storing this data with the user and trustworthy under user control, it becomes possible to perform learning analytics over time and in diverse educational contexts. Tools can be developed to support learners in understanding their own learning approaches from their own data, as well as supporting wider learning analytics carried out across populations, with user consent. The use of Semantic Blockchains makes this possible; without the security and trust, and the common data models enabled by Linked Data, it would be considerably more difficult to carry this out.

5. A case study in lifelong learning

In the context of the QualiChain²⁴ research and innovation project, we are investigating how Blockchain technologies can support lifelong learners throughout their learning journey and in advancing their career. QualiChain brings

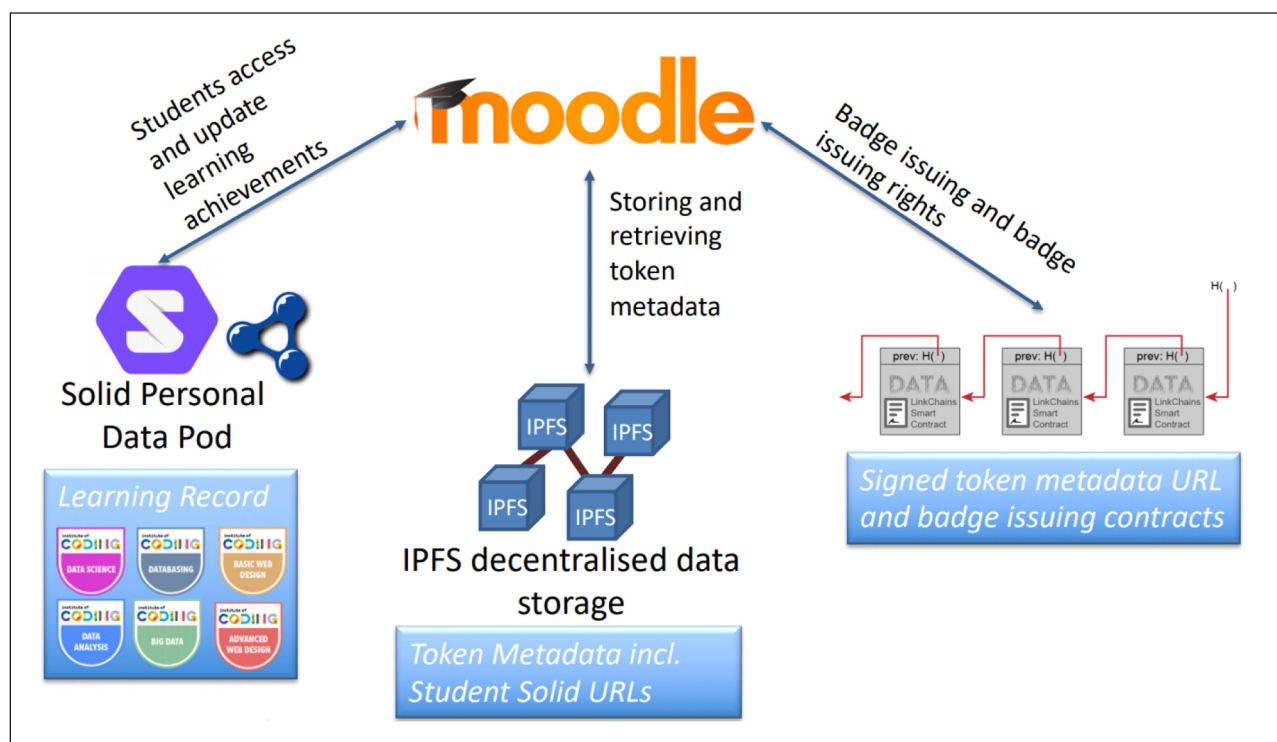


Figure 3: A Learning Management System (Moodle) communicating with the three main components of a Semantic Blockchain.

together a consortium of government agencies, universities and private companies across Europe, to investigate the technical, political, socioeconomic, legal and cultural impact of blockchain-based decentralisation solutions on education. The project is targeting four key areas for exploring the impact of decentralisation on education: (i) lifelong learning; (ii) smart curriculum design; (iii) staffing the public sector; (iv) providing HR consultancy and competency management services.

In order to explore the impact of decentralisation specifically in lifelong learning, we are conducting a pilot case study based on the learning scenario described in Section 3 and on the Semantic Blockchain technologies described in Section 4 of this paper. The main objectives of this pilot case study are the following:

- awarding lifelong learners with transparent and immutable educational accreditation;
- offering lifelong learners personalised recommendations based on their learning achievements;
- supporting lifelong learners in reaching their personal and professional learning goals.

5.1 Methodology

The methodology of this pilot case study consists of the following 3 phases:

- *Phase 1: Requirements elicitation.* In this phase, requirements are elicited from representative groups of stakeholders from the education community. These requirements drive the implementation of the case study in Phase 2.
- *Phase 2: Implementation and deployment.* In this

phase, the requirements elicited in Phase 1 are addressed through the implementation of Blockchain-based decentralisation solutions for lifelong learning. These solutions are then deployed in various lifelong learning contexts for use by members of the education community.

- *Phase 3: Evaluation.* In this phase, the decentralisation solutions implemented and deployed in Phase 2 are evaluated by members of the education community. To this end, a variety of evaluation instruments are employed, including surveys and interviews, for the collection of both qualitative and quantitative evaluation data.

We have currently concluded Phase 1 of the pilot case study and will be initiating Phase 2. During Phase 1, we engaged potential stakeholders from the education community via a series of consultation workshops. Participants in these workshops were early and late career researchers, lecturers, technologists and professionals from the educational sector. An average of 20 participants attended each consultation workshop. The series of consultation workshops was delivered within the following international conferences in the fields of open education and educational technology:

- The EATEL Summer School on Technology Enhanced Learning (JTELSS 2019), 3–7 June 2019, Bari, Italy;
- The Association for Learning Technology Conference (ALTC 2019), 3–5 September 2019, Edinburgh, UK;
- The Online, Open and Flexible Higher Education Conference (OOFHEC2019), 16–18 October 2019, Madrid, Spain;

- The Open Education Global Conference (OE Global 2019), 26–28 November 2019, Milan, Italy.

During these workshops, participants were introduced to Blockchain and Semantic Blockchain technologies, as well as the scenarios that apply these technologies in lifelong learning. In particular, participants explored the ways that ePortfolios, accreditation, tutoring, as well as other aspects of teaching and learning can evolve within a decentralised ecosystem based on the Blockchain. We were thus able to collect the feedback of participants about the decentralisation paradigm and specifically about its potential in lifelong learning. It should be mentioned that the collected feedback was not limited to decentralisation. Instead, participants reflected on the overall challenges currently faced by lifelong learners and how these challenges can be potentially addressed by educational technologies.

In order to document requirements for our pilot case study, we asked participants to produce learning scenarios that made use of Blockchain technologies in the context of lifelong learning. More specifically, participants were asked to work in small groups in order to brainstorm the following aspects of learning scenarios:

- *Persona(s)*: Who are the typical users in this scenario and what do they wish to accomplish?
- *Requirements*: As persona “X”, I want to do “Y”, so that I achieve “Z”.
- *Use of Blockchain*: How can the Blockchain be used in this scenario?
- *Related resources*: Any links/publications/other resources that are relevant to this scenario.

These group brainstorming activities were followed by plenary discussion sessions, where participants presented and discussed their scenarios.

5.2 Findings

Figure 4 summarises the main findings from the group activities and discussion sessions. These findings are presented in the form of requirements derived from the learning scenarios produced by participants of the workshops, as well as from the main takeaway points of the discussion sessions.

First of all, participants pointed out the need for ePortfolios to aggregate immutable formal and informal

qualifications that will be easily validated by employers and educational institutions. This will help streamline the admission processes in universities and the hiring processes by employers, as well as eliminate falsified qualifications.

Participants also highlighted the need for learners to be guided on how to build lifelong learning pathways in order to achieve their learning goals. These learning goals can be aligned with job market needs for improving the learner’s employability, or they can be associated with the learner’s personal progression ambitions. Acquiring micro-credentials can help lifelong learners achieve these goals by studying short online courses and earning professional or academic credentials (Ifenthaler, Bellin-Mularki & Mah 2016; Lemoine & Richardson 2015).

Micro-credentials are rapidly emerging and gaining popularity among lifelong learners, as they address their needs for granular certified learning. Renowned educational institutions from around the world are currently offering a continuously increasing range of micro-accredited courses, thus providing opportunities to pursue further study in a variety of specialised fields (Caudill 2017; Hunt et al. 2019; Lemoine, Wilson & Richardson 2018; Mischewski & Christie 2018).

Career counselling also featured in the learning scenarios and discussions of participants of the workshops. It was pointed out that job seekers are in need of acquiring a comprehensive overview of the job market and the latest market trends, so that they can make informed decisions about the next steps in their careers.

Finally, data ownership and privacy requirements were deemed quite important by participants of the workshops. It was highlighted that learners and job seekers should own their digital identity and the data in their ePortfolio. Additionally, they should be able to control who accesses their identity and their ePortfolio, which data is accessed and for how long.

5.3 Discussion

The elicited requirements largely validate the initial scenario of this pilot case study, as this was described in Section 3 of this paper, while helping us further expand it. In particular, we will be addressing the validation of both formal and informal qualifications in the form of Smart Badges. We will also be facilitating the building of lifelong learning pathways via personalised course recommenda-

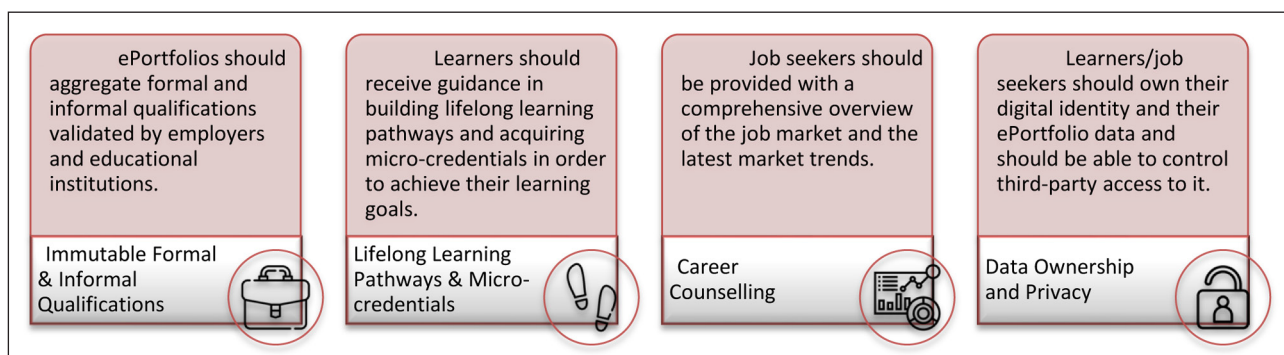


Figure 4: Requirements elicited for the lifelong learning pilot case study.

tions, which will help learners choose their next online or offline course, towards achieving their learning goals. Additionally, the personalised course recommendations will include micro-accredited courses, in order to facilitate the acquisition of micro-credentials by lifelong learners.

With regards to the career counselling requirement, personalised job recommendations will provide job seekers with advice on their next career steps. We are also contemplating offering detailed overviews of the job market and its latest trends via interactive dashboards, based on the ones we have developed in the context of the European Data Science Academy (EDSA) project (Dadzie et al. 2017).

We will be extending our pilot case study to address data ownership and privacy requirements by employing decentralisation solutions, such as the Solid platform (Sambra et al. 2016) and the FAIR TRADE framework (Domingue, Third & Ramachandran 2019). Solid is a decentralised platform for social web applications, where the data of users is managed independently of the applications that create and consume this data. This approach enables users to choose where their data resides and who is allowed to access it. The FAIR TRADE framework builds on top of the Solid approach by defining a set of dimensions relevant to data management in decentralised contexts. The framework can therefore be used for describing and evaluating the management of decentralised data solutions, as well as for the development of best practices in the developing field of decentralised data management.

Finally, we will be looking into ways of implementing Self-Sovereign Identity (SSI) for learners and job seekers. SSI is a technology that adds a layer of trust to digital interactions, thus allowing individuals to own and manage their digital identity (Mühle et al. 2018). There are several implementations of SSI in the literature, largely based on the use of Blockchain technology (Baars 2016; Othman & Callahan 2018; Stokkink & Pouwelse 2018).

6. Conclusions and next steps

This paper has presented the different applications and impact of Blockchain technology on online education and lifelong learning. We have presented a decentralised approach that enables learners to plan their learning journey more efficiently based on their desired career trajectory and offers them full control and ownership over their learning artefacts and processes. We have also discussed various approaches to the Semantic Blockchain and their applications on online education. The Semantic Blockchain offers a solution for bringing together all acquired learning experiences and accreditation, in order to form a coherent picture of an individual's lifelong learning. Impact on lifelong learning is significant, as learning experiences and accreditation can be acquired from diverse independent sources and according to different learning approaches, contexts and standards.

We are currently conducting a pilot case study for introducing decentralisation solutions in lifelong learning, aiming to offer transparent and immutable educational accreditation to lifelong learners, as well as support them in their personal and professional progression. Engaging communities of stakeholders through consultation

workshops has provided us with a valuable insight into the lifelong learning challenges that stakeholders face and their proposed solutions. This consultation exercise has resulted in the elicitation of requirements for supporting different aspects of lifelong learning, regarding immutable formal and informal qualifications, micro-accredited learning pathways, career counselling, as well as data ownership and privacy. The next steps of this work will be focused on the implementation, deployment and evaluation phases of the pilot case study, throughout which we will be liaising with communities of stakeholders, so as to better understand, analyse and address their needs.

Notes

- ¹ <https://www.blockcerts.org/>.
- ² <https://openbadges.org/>.
- ³ <https://w3c.github.io/vc-data-model/>.
- ⁴ <https://w3c-ccg.github.io/ld-proofs/>.
- ⁵ <https://www.unic.ac.cy/blockchain/free-mooc/>.
- ⁶ <http://thenewstack.io/one-school-using-bitcoin-blockchain-authenticate-degrees/>.
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- ²³ <http://edsa-project.eu>.
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Competing Interests

The authors have no competing interests to declare.

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